Interventional Systems

IARP Workshop on Medical Robotics
Hidden Valley, Pennsylvania

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Introduction

"interventional system" ➔ many, many possible topics !!!

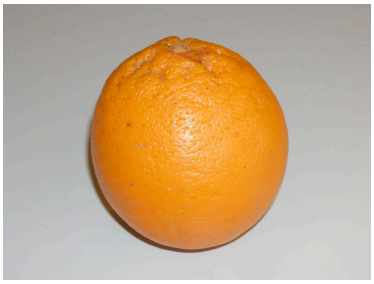
Just from MICCAI-2004 (*blue=VRAI Group research areas)*:
- Clinical system evaluation
- Computer-aided endoscopy
- Guidance of surgery & minimally invasive procedure
- Instrument and patient localization & tracking
- Intervention planning (invasive and minimally invasive)
- Medical Telepresence & Telesurgery
- Safety Issues
- Simulation & training systems
- Robotics

➔ *Impossible to provide a complete, comprehensive overview*

Why interventional systems?

- To extend a surgeon's sensor-motor capabilities
  - to perform scale translation (mm -> micron)
  - to solve accessibility problems
  - to enhance interpretation of 3D space
  - to deal with hostile environments
  - etc.

Consider an orange …



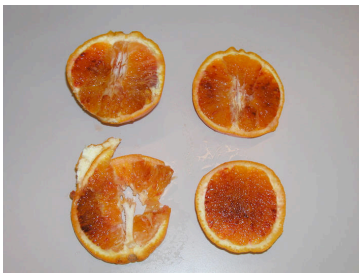
Problem definition

- An interventional system is used to identify, localize, reach, remove and/or interact with a region of interest (defined in diagnosis)

Diagnosis (pre-operative phase): from palpating to high-end visualization technique (« non invasive »)

CT
MRI
PET
US
X-ray
…

Slices



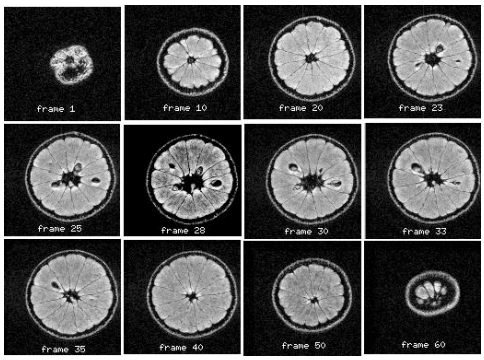
To higher description mode (Images to Models)

Image to models

- Slices encode what's on the inside
- Must interpret in terms of the imaging process:
  - material density, H concentration, electron density, etc.

Extract from a 3D data set (NMR scan) of an orange.

The images show magnetically excitable hydrogen as shades of gray

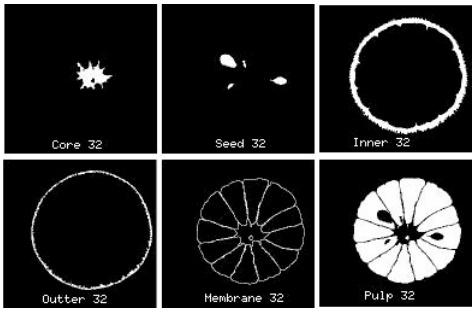


DSD – Lawrence Berkeley Lab

ROI definition

- Segmentation

This process often must be performed separately for each region/structure of interest



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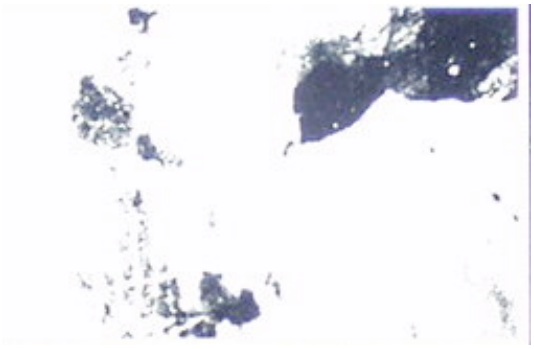
More difficult …

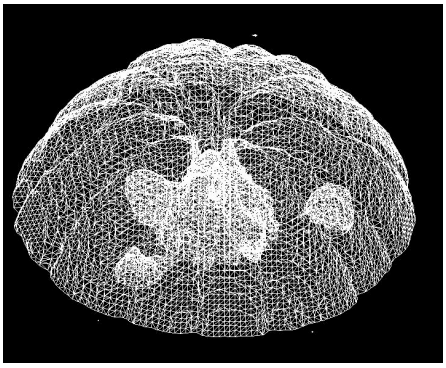
raw



Augmented

3D geometric models

- Geometric descriptions are used to enhance visualization
- Provides information for quantitative analysis (surface area, volume, mean curvature, topology, etc.)



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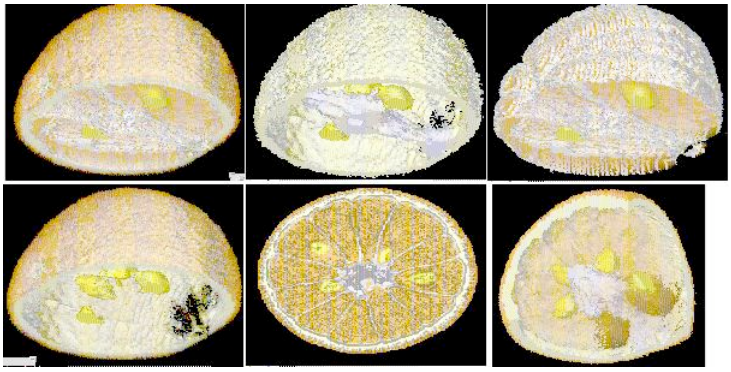
3D computer graphics models

- Provides tools to understand spatial features and relationships in the interior of an object / region / structure of interest



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How to interpret information?

- What are the most appropriate visualization tools?
- Parameters that influence information quality
  - Intrinsic (defined by the object)
  - Extrinsic (defined by environment, including diagnosis tools)

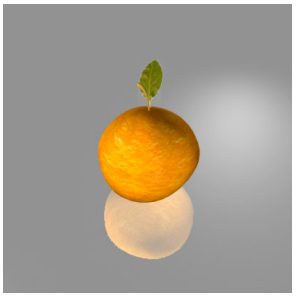
  No two « oranges » are the same
  (i.e., fat tissues influence diagnosis)
- External constraints may strongly influence information capture and analysis

  Capture timing can influence information content

Synthesizing information

- 3D Models

  Are static models useful for purposes other than pre-operative analysis and planning?



- To be useful during surgery, models of the ROI and structure of relevance need to be updated during the intervention!

  Medical constraints / Technical constraints
- Model update needs to fit medical requirements

  Accuracy + reliability

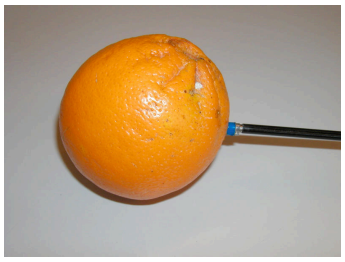
Assessing what is inside

- Conventional surgery (open and look)

  Interventional systems mostly provide visual feedback

- MIS (indirect access)

  Interventional systems provide visual & tactile feedback

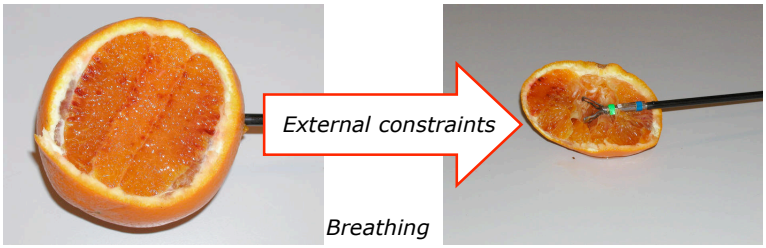


Key Problems

- How to acess the ROI in an optimal way? Some information is not accessible to the surgeon

  If the region defined by two contigeous « slices » is the « authorized » access plane, how do we inform the surgeon?

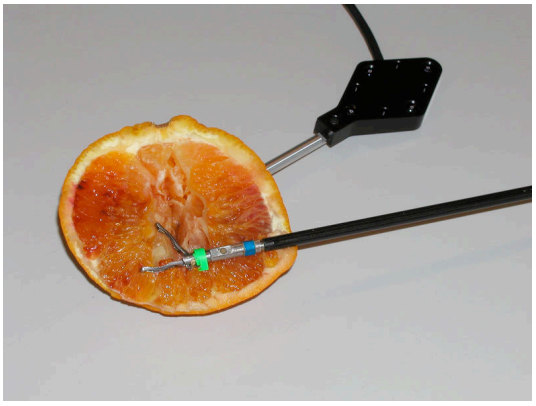
- 3D positioning
- How to verify and maintain validity of pre-operative data during the intervention?



Internal constraints (t, T, ρ, etc.)

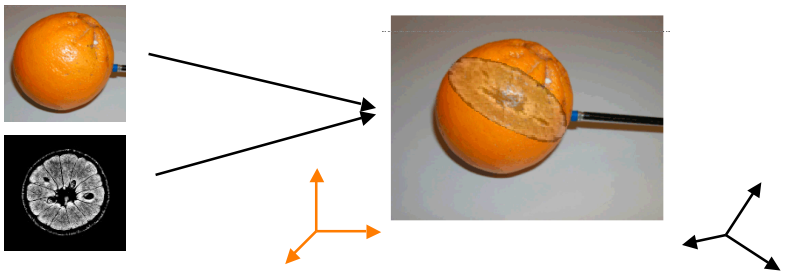
How to track changes?

- Cannot base navigation only on pre-operative data (not even with rigid structures !)



Merging pre + per-operative information

- registration



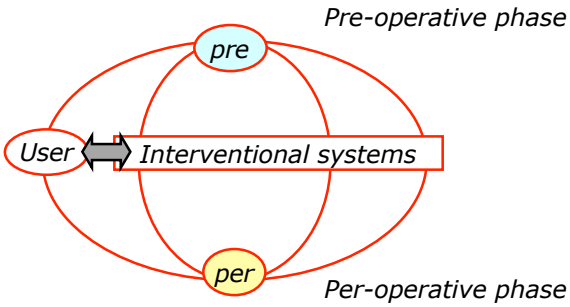
- Type of information
- Type of support to provide the merging

A definition of "interventional systems"

- To provide the right information at the right time using the right channel

  (note: right may be replaced by most appropriate)

- Human in the loop



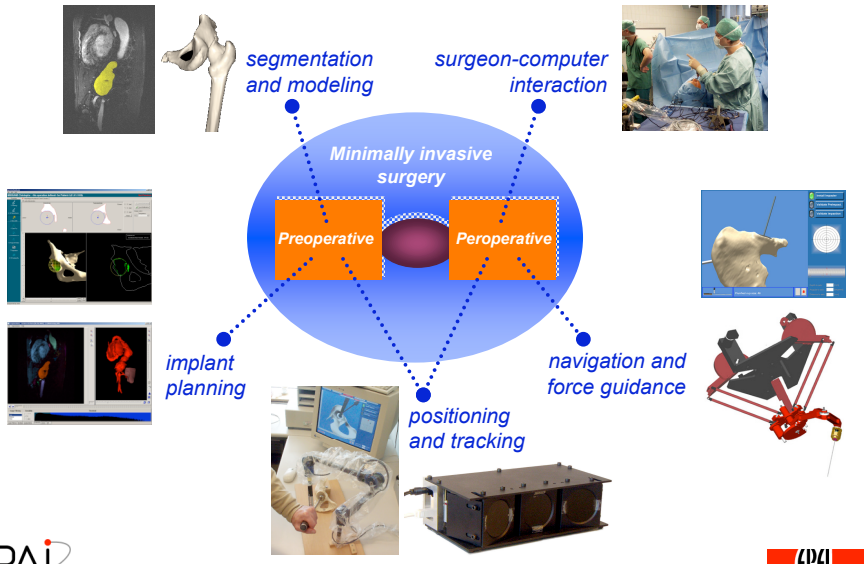
Questions to be answered

- Are interventional systems really needed?
  - From an engineering perspective, obviously YES!
  - What do surgeons really think?
- What needs to be achieved in order for interventional systems to be widely used?
  - What is the gold standard?
  - How do we get there from here?
- How/when should the surgeon be in the loop?
  - Always? Only sometimes?
  - What are the key tasks that have to be user performed?

More critical questions

- Are we on the right track? Are computer-based electromechnical systems the most effective way to achieve better medical treatments?
- What about biological alternatives, e.g. a virus used as transport mechanism to identifiy, reach and even interact with the area of interest?
- What about chemical possibilities? (combined with a "less invasive surgery" reactive system)
- Will we ever be able to perform surgery like on Star Trek?

Interventional systems



VRAI Interventional Systems
2004 IARP Workshop on Medical Robotics
EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

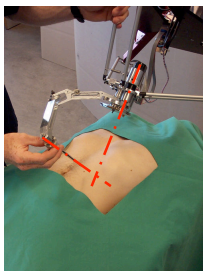
Some examples

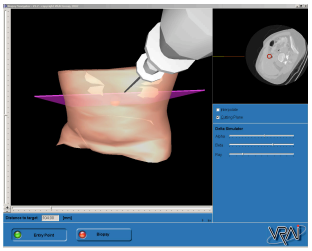
- *CALT : Computer Aided Laser Treatment*
- *Biopsy Navigator*
- *Liver transplant on living donor*

Haptics

Biopsy Navigator

- Provide qualitative force-feedback to surgeons during biopsy
- Kinesthetic cues: needle orientation, regions to avoid, etc.





Ongoing research

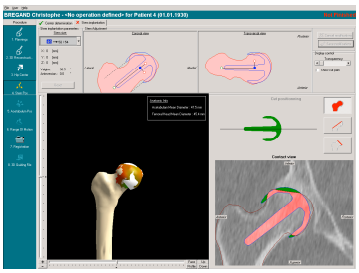
- Develop registration method
- Define calibration/validation process
- Preliminary field tests (HUG)

Interventional Systems
2004 IARP Workshop on Medical Robotics

Orthopedics

Total Hip Replacement (resurfacing)

- Software: segmentation/3D modeling, planning, navigation
- 6-DOF positioning arm



Results

- Initial system completed
- Positioning arm (v2), 0.2mm accuracy
- Registration methods

Ongoing research

- Refine navigation software
- Clinical testing (20+ trials)
- CE mark

Orthopedics

Clinical work (Year 3)

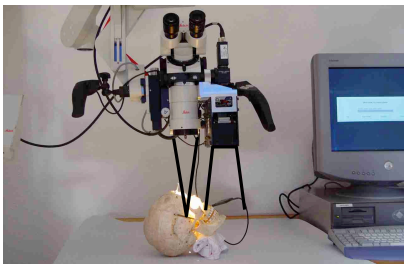
- Clinical testing (collaboration with Dr. Zambelli / HOSR)
- Complete software system + revised positioning arm

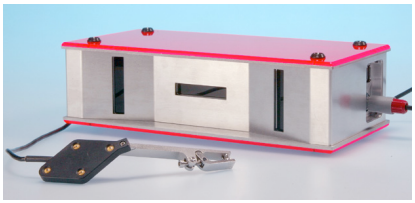
	Q3 (2003)	Q4 (2003)	Q1 (2004)	Q2 (2004)	Total
Hip surgery OR (CHUV)		2	3	10	15
Hip surgery OR (Nuffield)				2	2

Optical Tracking

easyTrack

- Real-time, low cost, low weight
- "Local area tracking"
- Can be directly mounted on surgical hardware (eliminate relative tracking error)





Ongoing research

- Wireless marker prototype
- Robot-based calibration
- Clinical tests (Inselspital)
- Develop biopsy and radiotherapy applications (HUG)

Surgeon-Computer Interaction

M/ORIS

Medical / Operating Room Interaction System (M/ORIS)

- multimodal framework to make the use of computer equipment in OR easier and faster
- give operating surgeon direct control of CAS UIs
  in complement of existing techniques
- perform automatic activity monitoring to assist surgeon
  without explicit command from the surgeon

direct : Non-Contact Mouse

- use input from stereo camera
- robust hand detection and tracking
  includes error detection and recovery procedure
- replaces traditional delegated control approach

Optical Tracking

Clinical work (Year 3)

- Surgical microscope field-testing (collaboration with Project 3)
- Radio-therapy feasibility study (Popovsky / HUG)

	Q3 (2003)	Q4 (2003)	Q1 (2004)	Q2 (2004)	Total
Liver surgery OR (CHUS)		2	3		5
ENT OR (Inselspital)				2	2
Radio oncology OR (HUG)				3	5

Conclusion

- Many questions were raised in this overview.
- Probably as many (or more) are still waiting in the audience.

Should be an interesting workshop !!

This talk was not (yet?!) sponsored by an orange juice company …